ON THE SEXUAL DIFFERENCES OF THE CHROMOSOME GROUPS IN GALGULUS OCULATUS.[1]

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An examination of the spermatogenesis of *Galgulus oculatus* together with a comparison of the male and female chromosome groups, has brought to light a new type of sexual difference in respect to the chromosomes. With this is correlated a new type of distribution of the chromosomes in the formation of the spermatozoa. On account of the interest of these facts, both in themselves and in relation to the theory of sex determination advocated by McClung, Stevens and Wilson, it seems desirable at the present time to offer this preliminary note on the subject. As soon as additional material can be procured, I hope to study and describe the facts more in detail ; but those here presented, are shown beyond a reasonable doubt by the material now available.[2]

The number of chromosomes in the first maturation divisions is somewhat difficult to determine with certainty, owing to the fact that associated with them are always a greater or less number of deeply staining bodies resembling yolk granules, large numbers of which are also present in the general protoplasm of the spermatocytes in this genus (Fig. 1, *F*, *G* and *H*). I hope to overcome this difficulty in later work by means of differential stains. These granules can, however, be distinguished from the chromosomes by their smaller size and spherical form. A comparison of a number of equatorial plates of this division shows that the number of chromosomes is almost certainly twenty. All of these divide equally so that the secondary spermatocytes receive twenty chromosomes each. In the specimens figured the chromosomes do not show any definite arrangement, but in some cases, fifteen

[1] By some later writers, the generic name of this species is given as *Gelastocoris*. For the sake of avoiding confusion, I shall retain the term *Galgulus*.

[2] This material was collected by Prof. E. B. Wilson, in North Carolina, and given me for study. I wish to thank him for helpful suggestions and criticisms. He also kindly made the photographs for me.

of them arrange themselves in the form of a ring, inside of which are the other five, which in this division are quite separate.

The chromosomes seem to vary considerably in size and shape, but this is merely due I think to various degrees of foreshortening, produced by slight differences of position. However, some are

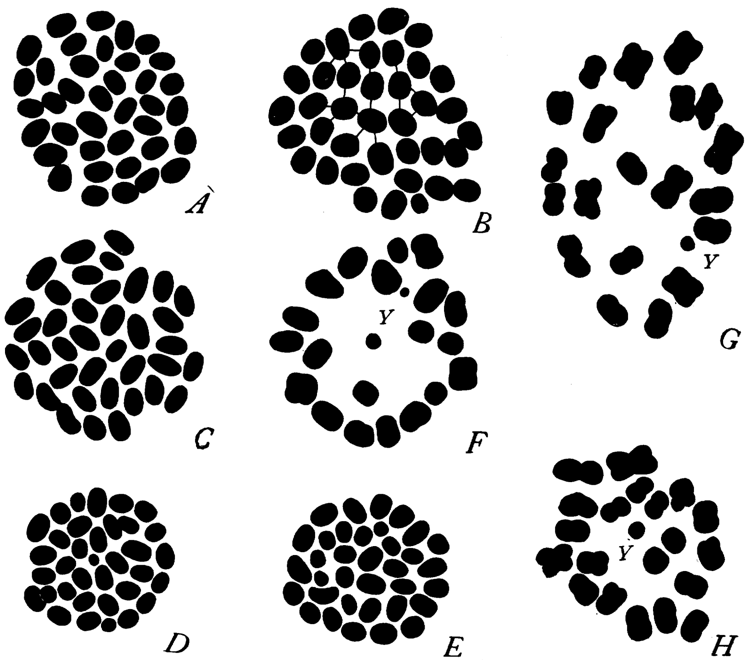

FIG. 1.[1] *Galgulus oculatus.* *A*, *B* and *C*, metaphase of female (oögonia or follicle) cells, polar view, showing thirty-eight chromosomes; *D* and *E*, metaphase of spermatogonial cells, polar view, showing thirty-five chromosomes; *F*, *G* and *H*, metaphase of the first spermatocyte division, polar view, showing twenty chromosomes and the granules y. *A*, *B*, *C*, *D* and *E* are magnified 3,105 diameters and *F*, *G* and *H* 2,009 diameters.

evidently quadripartite and some bipartite. From my figures some may be inclined to believe that the granules may be chromosomes, but the number twenty is verified by the fact that the

[1] All of the figures were very carefully drawn with a camera, a 2 mm. oil immersion (Spencer) and compensation ocular 12 (Zeiss). Some were enlarged once and some twice by means of a drawing camera which magnified $1\frac{6}{11}$ diameters. Although some error is unavoidable at such an enlargement, I have used great care in correcting, and the chromosomes are not schematized in the least, as can be seen by a comparison of the drawings, Fig. 2, *B* and *F* with the photographs, Fig. 3, *A* and *D*.

metaphase figures of the second division, without exception show twenty chromosomes. Again I have counted the chromosomes. in serial sections of the prophases before the nuclear membrane breaks down. At this time, there are no granules within the nucleus and several counts showed twenty chromosomes each.

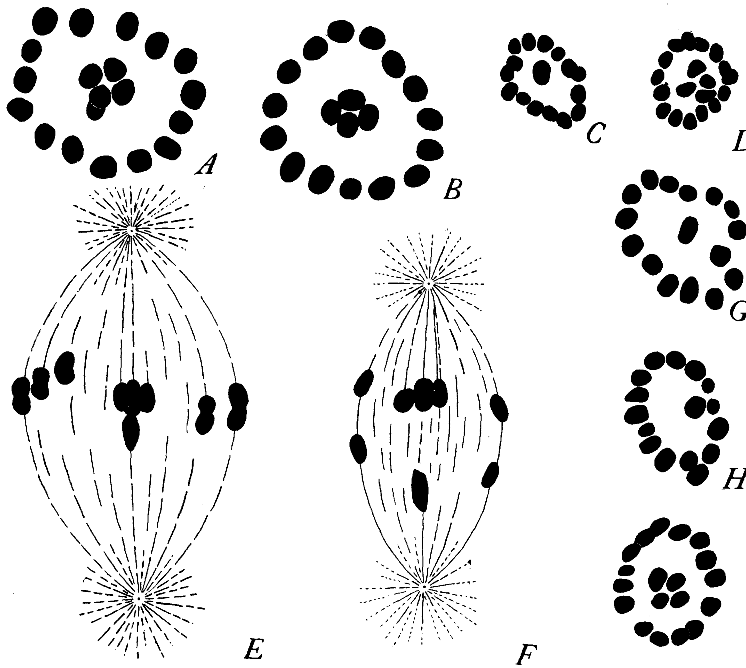

FIG. 2. *Galgulus oculatus.* *A* and *B*, metaphase figures of the second spermatocyte division, polar view, showing the ring of fifteen chromosomes and the pentad group in the center — in *B*, the chromosome beneath the four group could not be shown without displacing it; *C* and *D*, late anaphases of the second division, polar view, showing the unequal distribution of the chromosomes; *E*, side view of metaphase, second division, showing the typical arrangement and position of the pentad group — the spindle in both *E* and *F* is diagrammatic and merely shows size relations; *F*, side view of the early anaphase, second division, showing the manner in which the chromosomes of the pentad group separate; *G*, *H* and *I*, early anaphases of the second division, showing the chromosome distribution to the two classes of spermatozoa. All figures are drawn on the same scale and magnified 2,009 diameters.

The second division, which follows immediately after the first, shows a remarkable regrouping of certain of the chromosomes. Fifteen of the twenty take up the position of a ring, within which is a definite compound element formed by the remaining five.

These are now arranged in a pentad group, which always shows the same composition and occupies the same position. Four of these five chromosomes are grouped very closely together and lie in one plane, while the other one is either above or below this group of four, lying close to them on the other side of the equatorial plane (Fig. 2, *A*, polar view of the equatorial plate; Fig. 2, *E*, and Fig. 3, *C*, side views). The fifteen chromosomes in the ring divide equally, while the chromosomes of the central pentad do not divide individually, but the group as a whole separates in such a manner that one chromosome passes to one pole

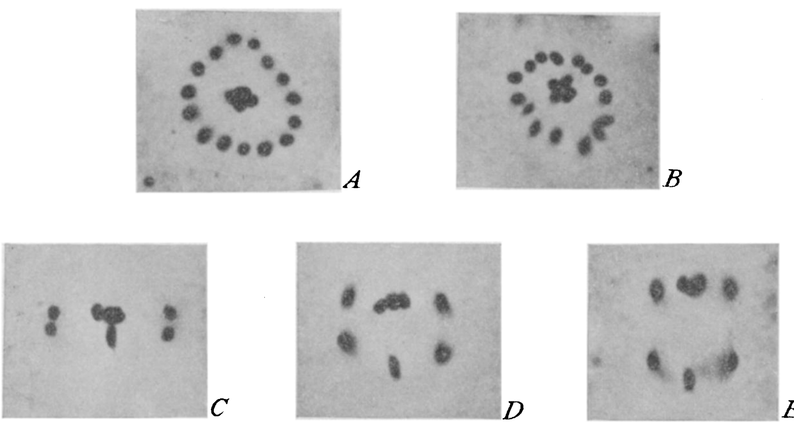

FIG. 3. *Galgulus oculatus*. *A*, metaphase figure of the second division, polar view, showing the ring of fifteen and the four chromosomes of the pentad group near the middle — the fifth chromosome of the pentad group could not be shown, as it lies beneath the four; *B*, early anaphase of the second division, polar view, showing the nineteen chromosomes which go to one pole; *C*, metaphase of the second division, side view, showing the typical position and arrangement of the chromosomes of the pentad group; *D* and *E*, anaphases of the second division, side view, showing the manner of separation of the pentad group, four chromosomes of which go to one pole and one to the other — only three chromosomes of the four group show, as all of them do not lie in the same plane. The photographic enlargement is 1,500 diameters.

and the other four to the other pole (Fig. 2, *F*, and Fig. 3, *D* and *E*). Two classes of spermatozoa are thus formed, which contain sixteen and nineteen chromosomes respectively. The early anaphase illustrating these two classes is shown in Fig. 2, *G*, *H* and *I*, and Fig. 3, *B*; the later anaphase in Fig. 2, *C* and *D*.

It yet remains to bring these two classes of spermatozoa into relation with the spermatogonial and oögonial numbers. Unfortunately but two spermatogonial metaphase figures are shown with entire clearness. They agree in showing each thirty-five chromosomes (Fig. 1, *D* and *E*). It may be thought that this evidence is not sufficient to establish the number with certainty. However, the number in these two cases is quite unmistakable, and as will be shown, it is the number to be expected from the numerical relations observed in the spermatocyte chromosomes and in the female. The female number (oögonia or follicle cells) is, without a doubt, thirty-eight (Fig. 1, *A*, *B* and *C*). The analogy which exists between the numerical relations here and in those forms with an odd chromosome, where the female number is one more than the male, makes the evidence all the more convincing that thirty-five is the male number in *Galgulus*. It is evident from these facts that the reduced female group must contain nineteen chromosomes; and that accordingly females are produced upon fertilization by the nineteen-chromosome class of spermatozoa; males upon fertilization by the sixteen-chromosome class.

Egg 19 + spermatozoön 16 = 35 (♂)
Egg 19 + spermatozoön 19 = 38 (♀)

So far, I have not ventured a new name for these characteristic chromosomes which make up the pentad group of the second division. At present I shall simply refer to them as differential chromosomes as Wilson, '06, has done in the case of the idiochromosomes.

Between the spermatogonial and the first spermatocyte divisions occurs a very prolonged growth period, during which the cell diameter increases approximately five times. Throughout this growth period, between synapsis and the formation of the chromosomes preparatory to the first maturation division, persists a large deeply staining body, more or less comparable in time of appearance and behavior, to the chromosome nucleolus of those forms in which it represents the odd chromosome or the idiochromosomes. I have not fully followed the history of this

structure in *Galgulus* and hence cannot definitely say what it is. It is possible that it is formed by the fusion of the five chromosomes which later appear in the pentad group of the second division.

At present there are not sufficient data to show the exact relation between this type of chromosome distribution and those already described. For this reason, I shall not attempt to homologize them in detail. Nevertheless, there is an evident similarity between the behavior of the pentad group as a whole and that of a single pair of idiochromosomes. In a general way, the four chromosomes of this group which go to one pole have the same relation to sex-production as a single large idiochromosome, while the one chromosome which goes to the other pole may be compared to a small idiochromosome.

With the discovery of this new type of differential chromosomes, it becomes more evident that the sexual differences of the chromosomes, even in the same order of animals, by no means conforms to a single numerical rule. In forms with one pair of idiochromosomes, the two sexes have the same number of chromosomes; in those with the odd chromosome, the female has one more than the male; and in *Galgulus*, the female has three more chromosomes than the male.

In many forms, as has been shown by Montgomery, Sutton and others, the spermatogonial and oögonial chromosomes may be paired two by two in respect to their size relations. In *Galgulus*, the chromosomes are too nearly equal in size to be readily paired, and the differential chromosomes are indistinguishable from the others.

Since in *Galgulus* there are two classes of spermatozoa; since the spermatogonial number is thirty-five and the oögonial thirty-eight, we have another support to add to the view that the two classes of spermatozoa are respectively male and female producing. In a recent paper, Correns has demonstrated by experiment, that in some plants there are two kinds of male germ cells produced in equal numbers, and that these two kinds are male and female determinants.

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